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Panel Perspectives on Existing and Future System Concepts – Mission Management and Interoperability

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1 INTRODUCTION

The presentation is meant as an introduction to the Symposium Session on Interoperability in the context of Integrated Systems-of-Systems. It describes concepts, theories and paradigms which are discussed by the SCI Panel, or which are relevant for its future work. These perspectives touch two of the five Areas of Interest of the SCI Panel, which are described in Figure 1.

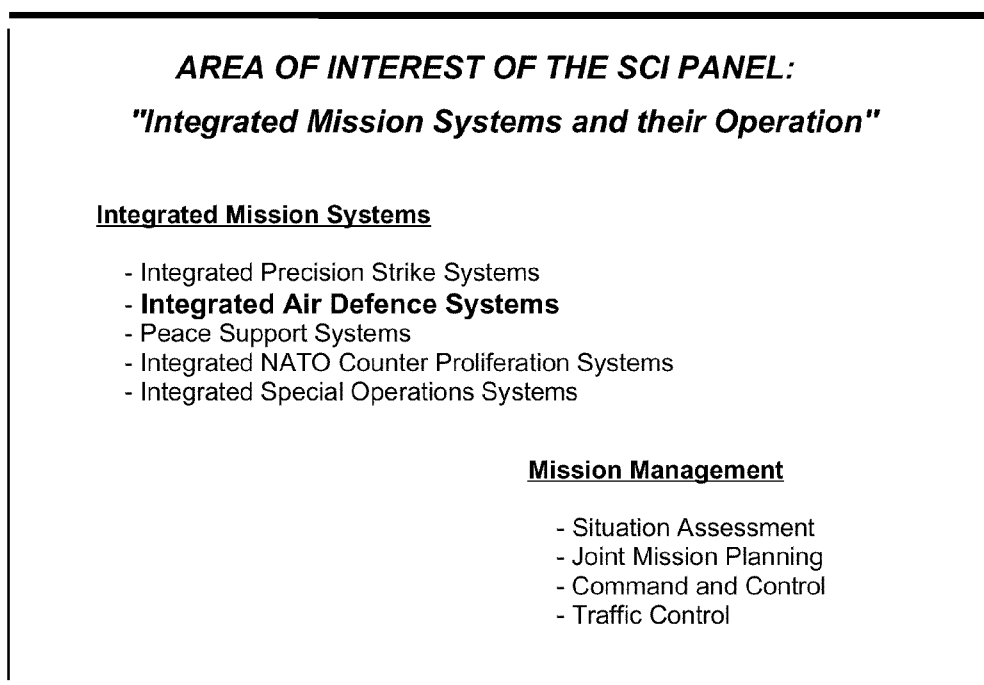


Figure 1

Integrated Mission Systems, which are the subject of this Symposium, are an example of Integrated Mission Systems. All RTO Panels are elements of a process in which concepts for improved military capabilities of NATO are generated, evaluated and finally realized. Figure 2 illustrates this process.

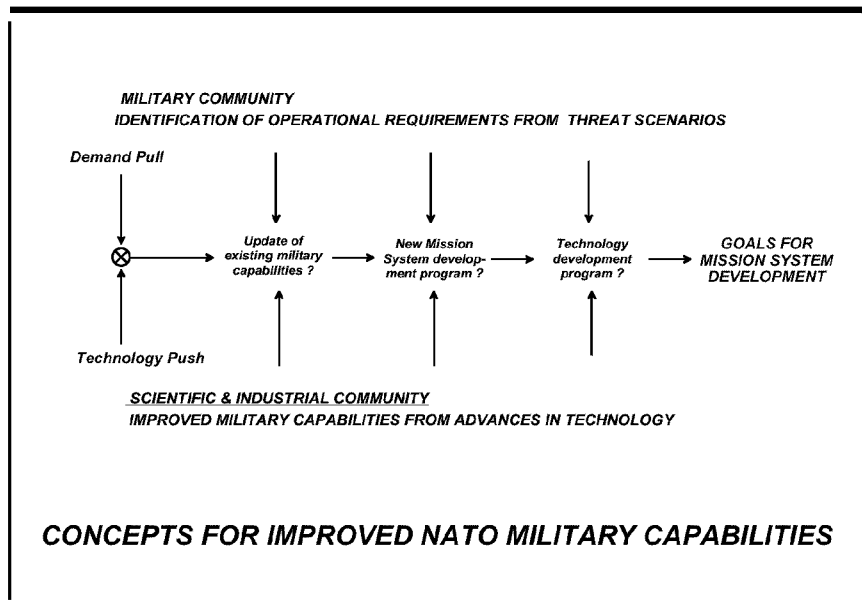


Figure 2

In this process, the Military Community normally identifies the operational requirements for new or improved weapon systems from emerging threat scenarios (demand pull). The Scientific and Industrial Community produces advances in technology, from which improved military capabilities can be derived (technology push). Interactions of both communities produce updates in existing military capabilities, new mission system development programs, or technology development programs. In the case of the SCI Panel, this takes the form of setting *goals* for Mission System development programs and for the corresponding technologies.

2 MISSION SYSTEMS AS MAN-MACHINE-SYSTEMS

The structure of Integrated Mission Systems is illustrated in Figure 3. This Figure is taken from the NATO/AGARD Aerospace 2020 Study (Vol 2) [1].

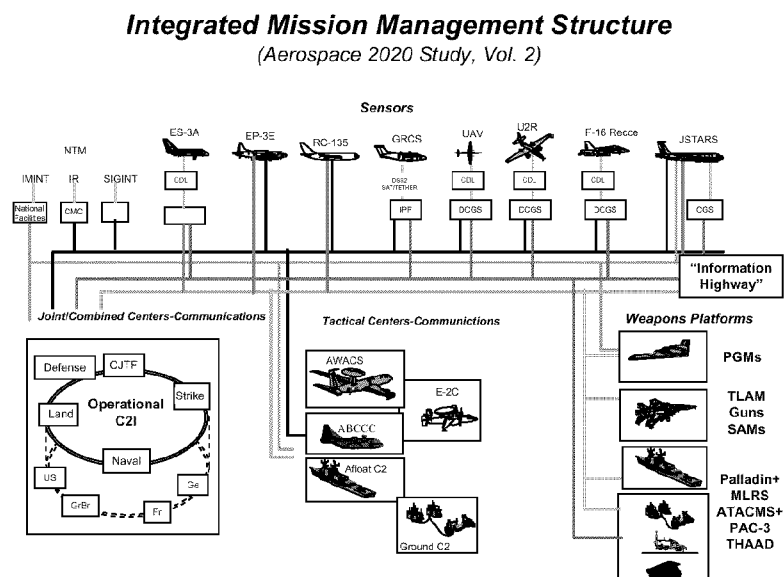
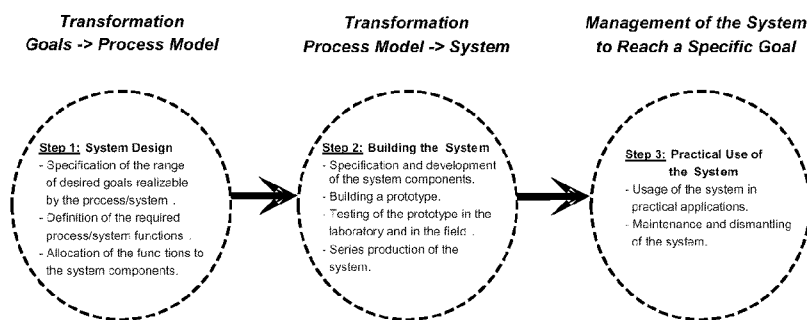


Figure 3

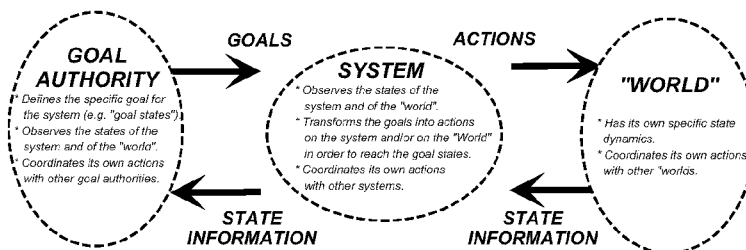
Sensor systems, Joint/Combined and Tactical Command&Control Centers, and Weapon Systems are tied together through powerful communication systems (“Information Highways”). This illustration shows the elements of an Integrated Mission System (*declarative system representation*), but hides the fact, that the system is operated and directed by Human Operators (commanders, operators, soldiers, etc.). In fact, Integrated Mission Systems are complex Man-Machine-Systems, and the understanding of their operations requires knowledge about such systems. Man-Machine-Systems are driven by *goals*. To illustrate this fact, we consider the Life Cycle of such a system, in Figure 4.



THE LIFE CYCLE OF A SYSTEM

Figure 4

After the definition of *goals* for a Mission System development program (see Figure 2), these goals have to be transformed into a Process Model with the corresponding Functions and System Components (First step: System Design). In a subsequent second step, the system components are developed, a prototype is built, tested and possibly a series production is started (Building the system). In a third step the system is used to reach specific goals in practical applications. This is the phase of the Life Cycle where concepts of Mission Management and Operability have to be considered in more detail. The Figure 5 illustrates the Paradigm for Mission Management, and will lead us to the important aspects of automation.

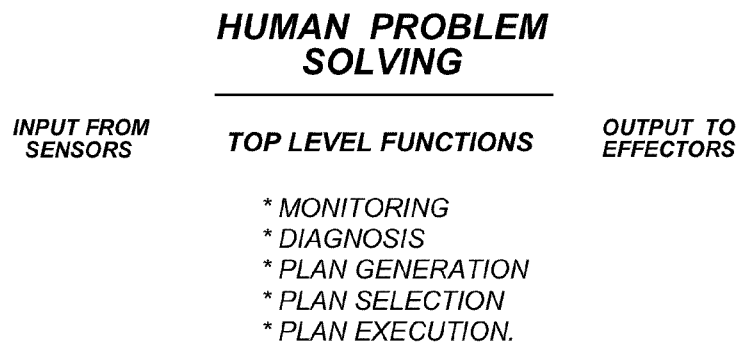


MANAGEMENT OF A SYSTEM TO REACH A SPECIFIC GOAL

Figure 5

The Mission System is employed to reach a specific military goal. This goal is defined by the „Goal Authority“, which can be a Command&Control Center, or the Supreme Military Command, or a Political Authority. The system transforms the goal into the appropriate actions towards the “World”, which is the area where the goal shall be reached. The world can be a hostile area, or a crisis region, etc. Sensors will produce information about the state of this world and feed it back to the system, and also to the goal authority, where it can be compared with the desired state of the world so that subsequent steps can be defined. This process has the form of a network of control loops. We call it the *procedural representation* of the Mission System, because it explains how the system operates. In addition to the control loops, a coordination function is important to harmonize the control actions in the loops with other parts of the military system.

It has already been mentioned that Integrated Mission Systems are complex Man-Machine-Systems which are driven by human operators to reach specific goals. This leads us to the question how human operators do their job. Figure 6 shows the basic “Recognize-Act-Cycle” of human goal-oriented behavior. This is also called the “Observation-Oriented-Decision-Action (OODA)” Cycle.



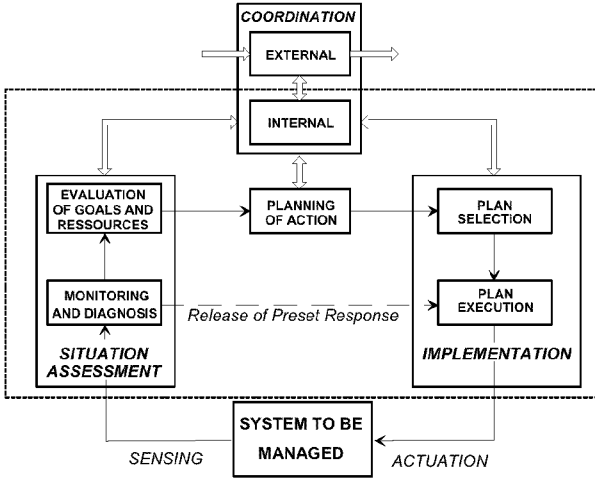
FUNCTIONAL ELEMENTS OF THE RECOGNIZE - ACT - CYCLE

Figure 6

Human operators transform sensor inputs into effector outputs by performing a sequence of Mental Functions (Monitoring, Diagnosis, Plan Generation, Plan Selection and Plan Execution) in order to overcome problems in reaching the desired goal.

3 MISSION MANAGEMENT AND INTEROPERATION

In Figure 5 we have discussed the Mission Management function, which is needed in order to reach the desired goal with the help of the system. The architecture of this Mission Management function - together with the elements of the Recognize-Act-Cycle in Figure 6 - have been studied in detail in Ref. [2]. This architecture is shown in Figure 7.

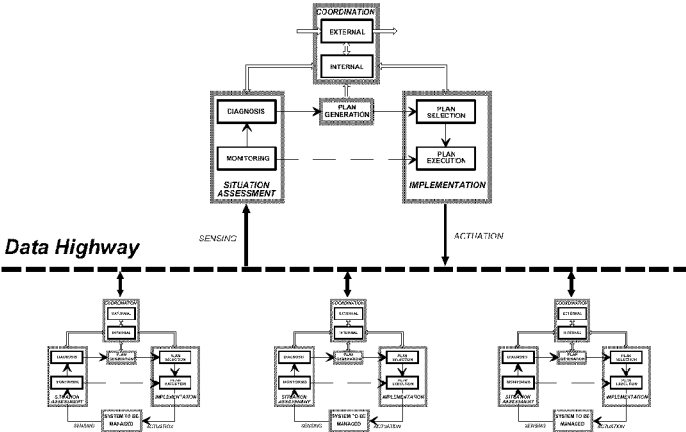


STRUCTURE OF MANAGEMENT FUNCTIONS

Figure 7

The block diagram describes the functional loop in Figure 5 with more details: An assessment of the present situation decides, whether a continuation of the Preset Response can take place, or if a new evaluation of the goals and of the available resources must be made. This evaluation generates possible plans for actions to change the situation in the desired direction, before a new plan can be selected to replace the preset response. This Mission Management function drives the system to the desired goal, independent of the fact if a human operator, or an automatic control system, or both carry out the described functions. A major goal of the automation of these functions in military mission management systems is the reduction of the Cycle Times (time constants) of the control loops involved. An other important functional element of this architecture of Mission Management is the Coordination Function. It controls the sequence of internal actions, and coordinates the actions of the loop with other (external) loops or systems. The lay-out of the coordination loop is the key to proper interoperation.

Integrated military mission systems (so-called Systems-of-Systems)- as considered in Figure 3 - contain a multitude of such elementary mission management loops in a well defined architecture. Figure 8 demonstrates, how such architectures can be constructed by proper coupling of elementary loops, using the coordination function.



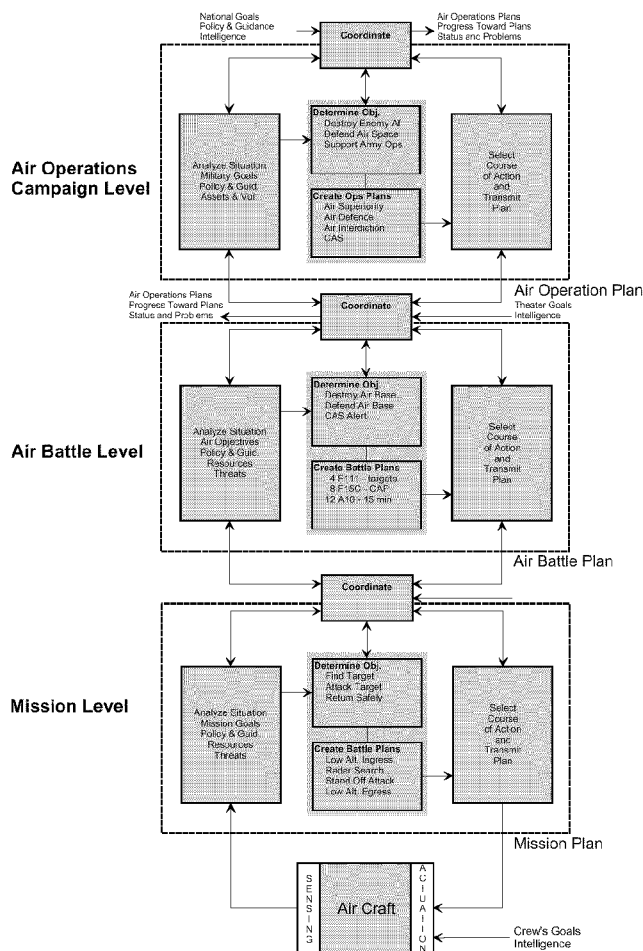
HIERARCHICAL COUPLING OF INTEGRATED MILITARY MISSION SYSTEMS

Figure 8

The example in this Figure shows a combination of a command mode (upper system) and a cooperative mode (lower three systems).

4 AIR DEFENCE OPERATIONS AND AUTOMATION

In Ref. [2] the ideas described in the previous chapter have been applied, to model Air Operations of the US Air Force as a multi-loop man-machine-system, presented in Figure 10.



EXAMPLE: PROCESS MODEL OF AIR OPERATIONS

See: AGARD-AR-325: *Knowledge-Based Guidance and Control Functions*. AGARD, January 1995.

Figure 10

The Figure shows only the control structure for one aircraft. In such multi-loop and multi-level systems-of-systems, cycle times (time constants of the involved control loops) typically range from one hour to two days (Figure 11), in present “manual” operations. It is expected that the introduction of automation can make these loops much faster.

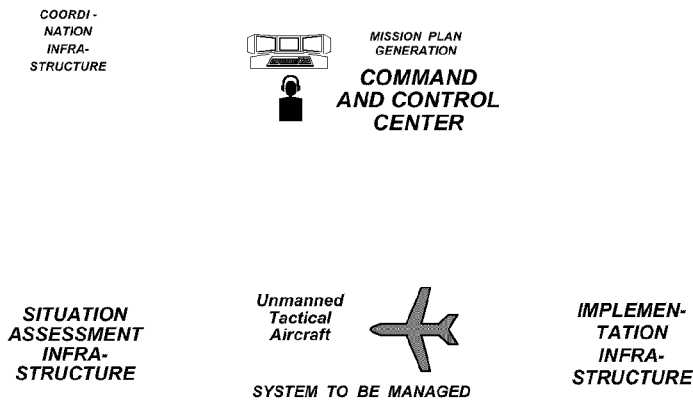
COMMAND & CONTROL LOOPS

<i>Unit or Weapon System Level</i>	<i>(< 1 h)</i>
<i>Force Level</i>	<i>(< 4 h)</i>
<i>Component Level</i>	<i>(< 24 h)</i>
<i>Theater/Joint Force Level</i>	<i>(< 48 h)</i>

TIME CONSTANTS OF THE COMMAND AND CONTROL LOOPS

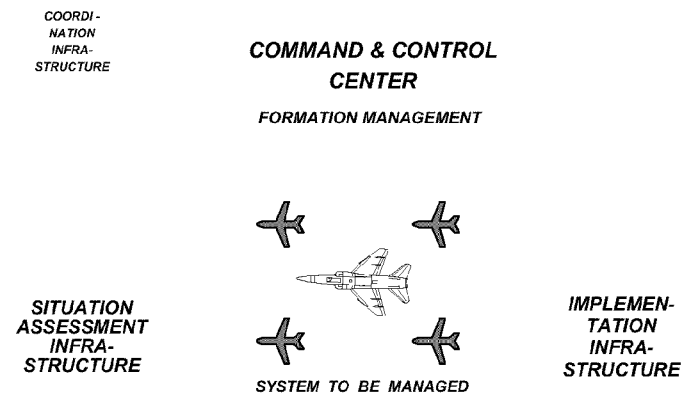
Figure 11

The following three Figures show examples for the integrated management of an Unmanned Tactical Aircraft mission, for the management of manned/unmanned flight operations, and for integrated management of the battlefield.



MISSION SYSTEM: UTA MISSION MANAGEMENT

Figure 12



MANAGEMENT OF MIXED MANNED/UNMANNED MISSIONS

Figure 13

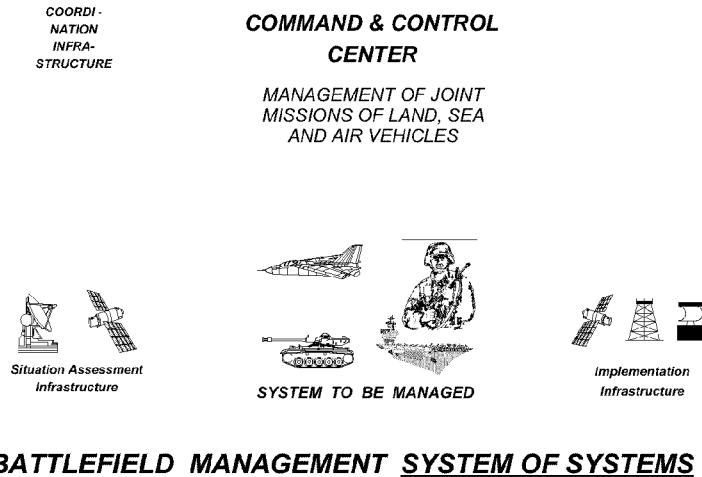


Figure 14

The important features of these loops are an integrated command&control function, integrated infrastructures for the implementation of the control operations, and for the situation assessment functions. The coordination of the actions of these management loops with other parts of the military system is performed through integrated coordination infrastructures.

5 PERSPECTIVES

It is expected that in the coming decades Total System Concepts similar to the one described in this presentation will be developed for Systems-of-Systems, like Integrated Air Defence Systems for multinational mobile crisis reaction forces, discussed in this Symposium. There are fundamentally two ways of introduction of such integrated architectures:

- To start with the realization of a Total System Concept from the beginning of the life cycle, and than to replace the existing systems by the new one.
- To transition stepwise from the presently existing multinational systems in a coordinated approach to the Total System Concept.

Experience shows that the second approach probably is the only way of introduction of the ideas of an integrated architecture for systems-of-systems. This will require agreement on the use of joint interfaces, architectures and the reduction of disparity of the equipment. Modularity of functions/subsystems and specialisation of the coalition partners on certain functions/elements would reduce the required effort for the transition to the integrated architecture.

The introduction of automation into this architecture is an important factor, in order to reduce the cycle times, and to realize more real-time flexibility in the command&control process.

The transition process should also be used to harmonize the infrastructures of the partners stepwise, in order to come to the required integrated infrastructures for control implementation, situation assessment and for the coordination function.

The stepwise transition to the integrated architecture is also a natural and flexible way of introduction of the technical basis for interoperability of the multinational forces.

6 REFERENCES

- [1] AGARD ADVISORY REPORT 360: AEROSPACE 2020 (3 Volumes). AGARD September 1997.
- [2] AGARD-ADVISORY REPORT-325: Knowledge-Based Guidance and Control Functions. AGARD, January 1995.